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Why Not Try Low Voltage?

By DAVID GNESSIN, E.E.I.

ALL radio transmitting and receiving equipment and electronic devices utilize a direct current power supply. This supply may be in batteries, d.c. generators, or rectified from the a.c. transmission lines. A number of ingenious methods have been prepared to provide this supply from different sources.

While the primary source of supply may be the local a.c. mains, the rectified d.c. is usually isolated by such means as a transformer, whose coupling is magnetic rather than electric, leaving the output at infinite resistance to the input. This rather obvious fact is brought out here because it serves to separate all other rectifiers and d.c. supplies from the *transformerless* or *universal* power supplies popularized with the advent of comparatively high-voltage filaments. The 25Z5 and the 117Z6 are examples of this series.

The disadvantage of circuits of this type is the necessity of series filaments with any rectifier drawing less than 117 volts, and the condition of having one side of the d.c. common to one side of the primary a.c. Thus, unless polarity is observed in plugging in to the receptacle it is easily possible to make the negative side of the d.c. "hot" at 117 volts to any of the numerous "grounds" about the house. Since the negative side of the d.c. may be common to the chassis, the field is wide open for severe shock with possible damage to the equipment or person. Therefore careful isolation is required, and coupling to other equipment becomes complicated.

With the 117 volt filament type of rectifier, the filament connection is simplified. The a.c. available from the line is used for both filament and plate. The rectified voltage may be used as the plate supply for any equipment, regardless of filament supply. Still, one side of the d.c. is common to the a.c. line. Also, the rectifier has a rather short life, due to the extremely long filament, winding and unwinding with the heat. (However, due to its convenience, pending research, one series of tubes with improved filament may be later standardized at 117 volts. Even more tubes of this nature may be forthcoming, despite the obstacles listed here.)

A step further in this type of circuit brings up the complex tube, offering greater convenience; rectifier and oscillator amplifier in the same envelope such as the 117L7 tube. Due to the high amplitude of ripple voltage in the rectifier sec-

tion, the magnetic field created by the a.c. envelops the oscillator or amplifier section in the same envelope, causing a 60 cycle modulation in the output. Extremely careful shielding in design may reduce this somewhat. Still, short tube life, great heat developed and d.c. common with primary current remain obstacles hindering efficient operation.

With low voltage on the plates of tubes, filter components would be considerably cheaper in cost, and longer lasting as well. Arc-overs in rectifier tubes will be abolished. High voltage sparking and high frequency radiation will be considerably reduced. Hum fields and cross modulation effects are negligible when filament voltages are 30 volts or less. Power-supplies might be obviated by using tubes developed to use the same filament voltage as the plate supply.

Experimentally, workable circuits have been developed using duplex tubes with plate voltages as low as six volts and lower. The loktal type 7F7 tube is one such tube.

Consideration must be given to the effective use to which this type of rectifier may be put that it may be evaluated on a general competitive basis with other power supplies, rather than as an isolated case with an occasional or intermittent application. The limitation here is only to low voltage, low current uses. Common examples are: Radio frequency signal generator, audio frequency tone generator, voltage amplifier for sensitive pick-up devices, such as photo electric cell pick-up, electronic weighing scale, M.O.P.A. oscillator stage. In all these cases a few volts of d.c. at a milliampere or two is enough to efficiently operate the devices.

While the 7F7 has been used in the experimental models the circuits are by no means limited to this tube. The 6F8G, 6C8G and 6N7GT have similar characteristics. For circuits where a greater plate voltage is required the 12 volt series, such as 12B8GT, 12SN7GT, 12A7, 12SR7, 12SQ7, and 12SF7 offer wide opportunities. If it is desired to avoid duplex tubes, separate rectifier tubes may be used for that purpose. The 7A6, giving an output of 8 ma. per plate, serves well. The 12H6 gives 12 volts d.c. at 4 ma. per plate. This is sufficient to operate small equipment without a power stage. Inspection of tube manuals will provide many new selections suitable for the circuit in mind.

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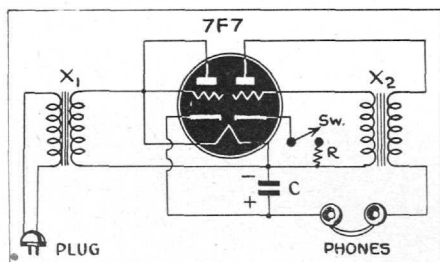
LOW VOLTAGE

(Continued from page 15)

Since this type of power supply requires a primary a.c. supply its use is limited to fixed (permanent installation) or 'plug-in' portable equipment. In the case of fixed equipment, size or weight is less of a consideration, and since the conservative type of fixed supply is more flexible, with greater voltage and current range, little improvement could be effected here in this regard.

In the matter of economy some gain can be realized with this new circuit. Even with fixed equipment one tube serving as both oscillator and rectifier is cheaper than separate tubes for each function. Besides, the cumbersome and bulky power transformer is replaced with a small filament transformer which supplies the 'high-voltage' (6 volts) as well. In this case the initial cost is lower (one tube and one filament transformer as compared to two tubes and filament-power transformers) and the replacement cost is as low or lower, element for element, while the operating cost (commercial current) is lower since the load is smaller.

However, it is in the field of plug-in portable a.c. operated equipment that the rectifier-oscillator comes into its own. In the matter of first cost, economy of operation, ease of repair and replacement, and size and weight it finds serious competition only in the flashlight cell battery supply. An experimental model of an audio tone generator using the circuit of figure 1 utilized as a 'code-practice' oscillator has been built and shows no change in characteristics after a year of regular use. Its picture is shown in figure 2.



—Courtesy Radio Craft.

Figure 1

Circuit of Audio Tone Generator

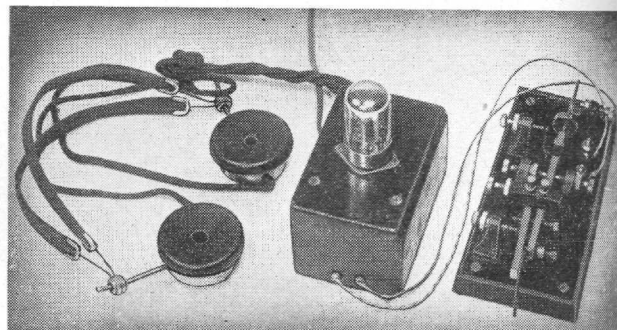
A battery supply would have shown a great reduction in strength, if indeed showing any life at all after this time. But then, twenty to forty cents would completely replace the battery supply. Thus we can't ignore batteries as excellent means of supply for portable equipment, especially for intermittent use.

The war has, of course, curtailed much new development along non-military lines. Tube

manufacturers, however, in preparing lines developed for military use offer a few tubes to become available after the war. These tubes are designed for low-voltage application. The very latest of this type is the 28D7. This is a double beam power amplifier for 28 volt operation. A few months ago it was developed to fulfill a need for an output tube which would deliver sufficient power at low operating voltages and thereby eliminate the need for auxiliary high voltage power supplies. Of primary importance in aircraft applications, the principal usage at present is confined to military requirements. Subsequent use in commercial equipment in railway cab signaling and perhaps in farm and certain car radios is anticipated.

It was found that certain other existing commercial tube types can be employed in 28 volt operated devices. A suitable output tube was not available prior to the release of type 28D7. The types 14J7, 14H7, and 14R7 are also available in this series. The 14 volt tubes are generally connected in series groups of two, utilizing the 28 volt power supply. This supply can be the 28 to 32 volt rural power system, the 24 to 28 volt aircraft batteries, two 12 volt maritime batteries for sea-going craft, etc.

In this series the plate voltage is not too critical, since they operate efficiently over a range of voltages. These tubes operated with the plate and screen voltages obtained from the 28 volt storage battery in aircraft are becoming rather commonplace for aircraft equipment. Inasmuch as the plate, screen and filament supply of the equipment will be subject to whatever voltage variations occur in the supply voltage, it is important to know how the performance will be affected by such changes.



—Courtesy Radio Craft.

Figure 2

Complete Audio Tone Generator Set

The operating supply voltage during flight will vary from 27.5 to 28.5 volts. When the plane is grounded, the supply voltage may drop to as low as 22 volts. In some instances a gasoline driven generator may be connected to the supply source while the plane is grounded, which may raise the

voltage to 32 volts. However, the power output, especially of the type 28D7 is very flat over a wide range of heater voltage. There is a drop in power output of approximately 3 per cent with a heater voltage change from 32 volts to 17.5 volts. A corresponding drop occurs below 17.5 volts, but the tube efficiency starts to drop.

Figure 3 shows a complete radio receiver using the tubes described above. The superheterodyne circuit with the proper coils will respond efficiently to signals up to 100 megacycles. However, like all superheterodyne circuits, the sensitivity will start to fall before 30 mc. The design features pre-selection, a.v.c. and push-pull output.

The first thing noted in the diagram is the absence of a power supply and rectification system. The single battery shown supplies all voltages. The first two tubes have their filaments connected in series across the battery. The next two tubes have the same type of filament connection. The driver and p.a. tubes are each connected across the battery in parallel. If the receiver is used intermittently, for a few hours at a time, no dropping resistors are necessary. On the other hand, if the equipment will be operating 24 hours daily, a heavy resistor should be placed in series with all filaments, of such value as to show a maximum voltage across the final 28D7 filament of 28 volts. This will insure longer tube life.

The meters shown in the plate and screen-grid circuits show the values of current in milliamperes for maximum signal. These values will prove a check for efficient operation.

Note the i.f. and detector stages use the duplex 14R7 tube, shown torn in two for clearer reading. Actually the two stages are in the same tube

envelope. The same 14R7 tube is used as voltage amplifier, but there the diode plate is not used, and is accordingly tied to the regular plate.

There seems at first to be a great deal of audio amplification for such a moderately sized receiver. This is necessary because of the low power amplification available at low voltage. The driver 28D7 and following p.a. 28D7 stages operate AB₂. In this manner they drive the permanent magnet speaker to a maximum output of 600 milliwatts. At this output the distortion is approximately 13%. For somewhat greater fidelity the receiver should be operated at less than maximum volume. The distortion for an output of 500 milliwatts is less than 10%, decreasing with the volume. For earphone operation (such as in aircraft) the last two stages may be disconnected (by the simple expedient of removing the last two tubes from their sockets, if need be) and the phones connected in the voltage amplifier stage. This will reduce the current drain to almost half its normal value—a practice worthy of note in portable equipment. In this case the distortion is only one or two per cent.

Tubes like the 28D7 draw 0.4 ampere filament current and up to 30 milliamperes or more plate current. In push-pull operation (this is possible since two beam power amplifier sections are built into one envelope) the plates draw 64 milliamperes. That makes the tube run at rather high temperature. To get the same output at $\frac{1}{4}$ the voltage, the tube would have to draw more than two amperes. That would be a very warm tube. Remember, these are small receiving tubes. Then again, in order to get satisfactory amplification and power an appreciable voltage drop from filament to plate must exist in order to

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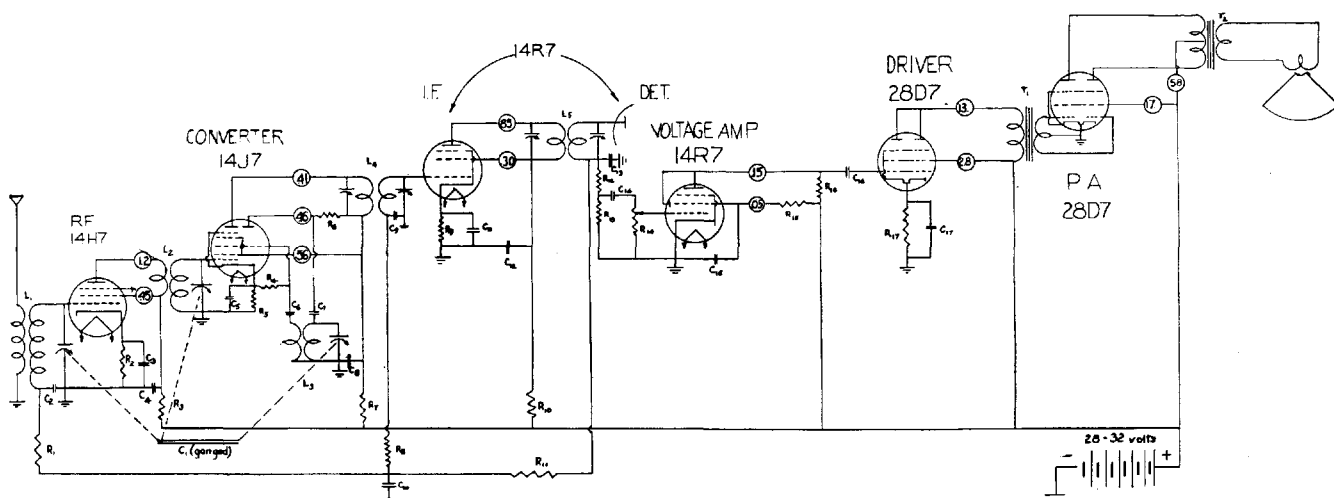


Figure 3—Complete Superheterodyne Receiver

tube manufacturers to provide the industry with tubes and circuits specifically designed for low voltage application.

LOW VOLTAGE

(Continued from page 21)

accelerate the filament electron flow. As this e.m.f. is reduced the filament must be designed to put out more electrons, requiring more filament current. That approaches an impossibility, since the current varies with the voltage, and here the filament voltage is being reduced as well. Besides, with more filament current the tube will run still hotter. Also, distortion of the input signal due to the curved portion of the characteristic curve at low plate voltages will have to be overcome.

Despite these difficulties in design it is possible to look forward to some intelligent planning by